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CLASSIFICATION

CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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FILED

PRIORITY DATE

No. OF CLAIMS 7

LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

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Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the vall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the vall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 35 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential sorew element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads, to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38a, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For example, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 13.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $P_{\rm c}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve QA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A end B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

approximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

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Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble \$1 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1 2 device comprises a shaft element, an expanding die member attached to said shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to 5 contact said liner, an expander member slidably positioned on said shaft 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft to contact said expander member and to maintain said expander member against 9 said liner-forming member, whereby said liner-forming member is urged against 10 said liner by a substantially constant force.
- 1 2. In a device for installing an expanded metallic liner in a conduit wherein an expanding die is moved through a liner positioned in said 2 conduit to expand said liner: a cylindrical shaft element, an expanding die 3 Ŀ member attached to said shaft, said die member comprising a plurality of arm 5 members disposed around said shaft and being pivotable outwardly therefrom to 6 contact said liner, a cone member slidably positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft, and a constant force spring member positioned on said shaft to contact said cone member and to maintain said cone member in contact with said arm members, whereby said arm members are urged outwardly by a substantially constant force.
- 1 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing 2 plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

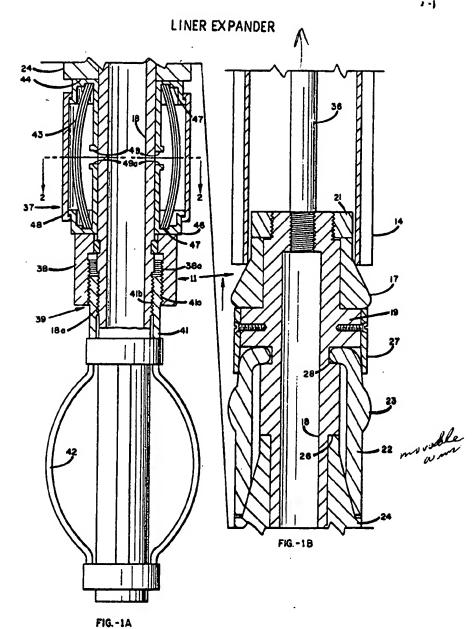
- 4. The device of Claim 3 wherein said compression means comprises a differential screw connecting said spring member and said shaft.
- 1 5. The device of Claim 3 wherein said stop means comprises a 2 sleeve-like element connected to said movable bearing plate member and 3 slidably positioned on said shaft and a member connected to said shaft to 4 limit the travel of said sleeve-like element.
- 1 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said shaft.
- 1 7. A device for installing an expanded metallic liner in a conduit 2 which comprises a cylindrical shaft element; an expanding die member mounted on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably 5 6 positioned on said shaft between said shaft and said arm members to urge said arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about 9 said shaft; an upper bearing plate member and a lower bearing plate member, 10 each slidably positioned on said shaft and contacting opposite ends of said 11 columns; limiting sleeves attached to each of said bearing plate members 12 and slidably positioned on said shaft; a shoulder member on said shaft; a differential screw element connecting said shoulder and said shaft to apply 13 14 a buckling load to said columns; said shoulder being engageable with the limiting sleeve connected to said lower bearing plate member, whereby the 15 16 axial travel of said bearing plate members is limited; said column members transmitting their buckling load to said arm members to urge said arm members 17 18 outwardly with a substantially constant force.

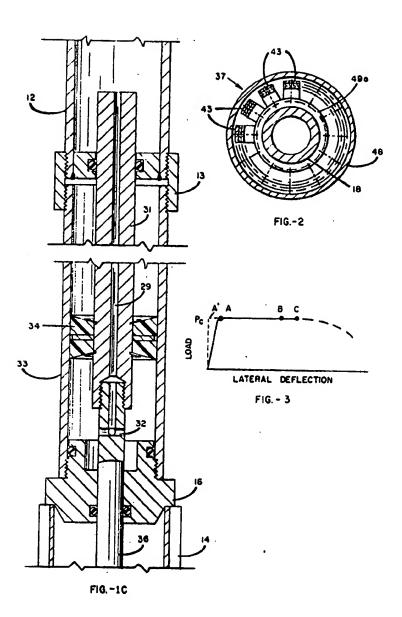
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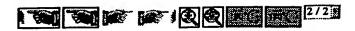
A. A device for expending a artallic line; havine a couched which device comprison a shaft almost, an anymoting of monter attached to said shaft closure, said die number comprising a movelle liner-forming number positioned on said shaft and being cadally novelle in respect thereof to contact said liner, as expender morber alidedly positioned on said shaft between said shaft ead said die number to move said liner-forming number from said shaft, and a constant farms spring number positioned on said staff, and a constant farms spring number positioned on said staff, and a constant farms spring number is urged against said liner-forming number, whereby said liner-forming number is urged against said liner by a substitutially constant forces.

2. In a device few installing an expended actabilic liner in a constaint wherein an expending die is moved through a liner positional in said susseint to support said liners a cylindrical short alment, an expending die meeber attached to said short, said die meeber comprising a plurality of are meeber attached to said short, and teing pluvishle interactly therefore to constant still liner, a cone member shidably puchlicmed on said short between said short and said are members shidably puchlicmed on said short between said short and a constant force opting number positioned on said staff to contest said cone member and to maintain said come member in contact with said are numbers, whereby said sem tembers are urged outsardly by a substantially constant force,

3. The ferrios of Claim & charact, and compare force spring anchor comprises a planelity of column fispeed accord eath chaft, a More bearing plate contex and a second bearing plate souther, cash of said bearing plate authors contecting opposite onto of said columns, at least one of said tearing plate numbers being moreholy positioned on said others and being in contact with said come number, stop more commerted to said starts to limit the axial traval of said morehole bearing plate number along said start, and compression mesons for colorising a letteral destruction in said columns.

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- . A, the device of Claim 3 wherein each compression process comprises a differential space expansion; and againg member and said shaft.
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- 6. The device of thate 3 whereis said columns have a mantangular even-metion, the width being greater than the Michaele, and being the wider face amount to the dismotor of said shaft.
- 7. A device for installing at expended establic liner in a cominti determined and priference as amount of the leading of a spatial shally said the senter comprising a planshity of are someone disposed arestially around the exterior of said shaft and bud-of pivotable outmarily therefrom to contact the liner; a stated expending states slidely hims agree of exprises are him but stude hims married thats hims so be ero optimizaty from said shelts a plurality of elemen columns, each being a long restingular omes-sertion and disposed structurentially short said chafts an upper bearing plate maker and a lower tearing plate scatter, such stidably positioned on said shart and contacting opposite onds of said me limiting alasme uttended to each of stift bearing plate members and alidably positioned as said statts a shoulder number on said shafts a ential amor closure commeting will shoulder and still shoth to apply sting look to stil enhance suit thouless being emphasize with the limiting misers semmeted to each looky bearing plate mester, whereby the arial trevel of each bearing plate members in limited; each column weathers branesitting their buckling look to onld arm numbers to urgs said arm graders convertily with a substantially constant force.

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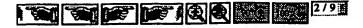
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Deputations, a cataod and apparetus here been developed for invialing on emphasist asiatite times in on cal wall or other conduit. Cypically, a correspicted about liner is imported in a condult which he in he hired, the greatest puriphosal-disserion of the liner being eligibily less through the liner placed in the appliedt, and a first-stone arguming size name a gross plantic dofumetion of the liner, which is equaled outs the inside of the acadmit. A souper-stage die on the tool team provides on shiltimal finer defountion of the liner to provide a moother, care finished surface on the incide of the liner and to searce some complete con the contact and the lieur. In a typical design of this type especing tool, the frieticual drug of the first-stage die supplies the expending force for the eccond-steps die, which expending force is a street function of the strength, or wall thickness, of the conduit is which the limer is being installed. For example, in limity oil well cusing, beary wall sering any owner a very high Erickianal fours which results in excessive e licing sequired to push the expender through the liner. The skion of the great forces required sty steal, is replace of the carries naring the installing tool. In fasteness where the interval e of the exchain to exceeded toos them that arcticipated, the resultin the tool to become stook in the entire, or otherwise damage to the ensing and the tool. He other dealgra, such as there a quantilever spring arrangement in employed in accessizion of in the a suign dis, various difficulties are encountered in obtaining a spring madranism baying the desired strength is continuation with the other spring. meteries, and with the tool dragging against the tweets will of the mondath after bring passed through the liner.

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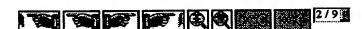




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Figure 3 is a typical plot of applied lock versus believiton for the constant force spring device of the Levention.

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In operation, the liner setting tool is essential at the surface, so described shows, and a glass cloth saturated with a restance material may be unapped around the corrugated tens to turn the liner. The assembly is lovered on oil, is then pusped under presence down the well tables and flows through nagemy 29 provided in policied rod 51, through parts 52 and into eyilader 35 consected to the upper and of the shoulder 16. Upon the application of find prisours to the cylinder, the pistes 34 second to polished red 51 nowe appearably in mylinder 35. As shown, rot 36 cornects polished rod 31 and shaft 15 spot sideh is mounted the Eirst-stage expending siz 17. Then the piston % moves towardly through the splinder 33 the expanding die 17 and the secondstage die 22 are draws apparelly into the corregated liner 15 and "iron out" the corruptions in the liner, so that the expended liner may contact the famile well of the casing in which it is being installed. Poritioned on the shaft below the expending member th is a comment turns spring master 37 which to employed to urge the expending number against the explaining sums 22 with a substantially sometant force. The force exacted equiest the exh methers being substantially notation, the force transmitted through the arm masters to the liggy and to the centag will be substantially constant so that aither skinking of the tool in the casing or repture of the casing is precluded. Or course, the three growled by the spring mester is preselected so that the frictional

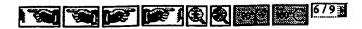




forces between the tool and the liner and the presence emerted defined the enting are maintained at presentended safe levels. The communications spring manhor essures that the emetest presence between the liner forming portion 20 of the sons 22 is great enough to pravide the desired deformation of the sade-

The equators force spring seasor 77 is alidebly nounted on the shart all end hald between the expending alongst 20 and a cylindrical lower chealder seasor 30 forcing a portion of a differential server alonest 39 which transacts the localing on spring number 37 to chart member 18. The differential server alonest comprises shaft number 18 as the certific of unick are set as a transfer like, the lower chealed runder 18 provided with transle thrusts 35 and thinkle number 31 provided with threads all and 315 as the certifies and the incider. The two server 45 provided with threads are source, such as square, molified equare, or form threads, to witherand very high loads and differ in pitch so that shoulder 35 is seemed appearity on the shart 18 when the shart is revolved relative to thinkle \$1. The schoolfer 36 is seemed to the shart 16 by splines 55 so that it can alide longitudinally, but it is not tree to rotate on the shart. Finally attached to the lower set of the thinkle is a friction number, such as but aprings \$2, a hydrallically equated friction yea, or other such device for frictionally consisted friction yea, or other such device for frictionally consisted friction yea, or other such device for frictionally consisted friction yea, or other such device for frictionally consisted with respect to the shaft. Frederically, the direction of the decilier number threads 35, with the pitch, or load, or threads 18a is slightly greater them that of threads 18a is slightly greater them shoulder service years allocations upwered allocity and a congression load is convict upwardly on apring alasmot 37 to unsee building. For example, one vertice account inside dismeter.

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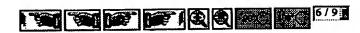


Donatest force spring element 37 comprises unions element 49, etractageously convicting or a phrality of alongsied solumn disposed around shaft 18. Upper bearing plate employ is in contact with the sport ands of the solumn and is aliabily positioned so shaft if to tracount the force of the agring longitudinally against the bottom and of expendes sendor sh. Lower bearing plate sendor 16 contacts the lower ands of the column and 10 moved spring plate sendor 16 contacts the lower ands of the column and 10 moved springly along the seart by longitudinal movement of lower shoulder 30 or a result of revolving differential moves almost 39. Greaves 17 set provided to send or the bearing plates, to form an upper case and a lower secs, into which the case of the column are inserted. These grooves may be chapted to contact with the chapt of the column make it section. A cover 16 may be employed to another foreign antier from the spring mechanism and to protect

A means for limiting the deflection of the columns to required. Although the column element functions in a backled condition, application of . properties accurately look thereto would seems total failure or reptare of the a. Therefore, a pair of stops 69 and 150 are provided for this purpose. As shown, the stope are rigidly connected he the bearing plates, and, in effort comprise upper and lover limiting slarves positioned on the shaft to slide longitudinally therem. The ends of the stops may nown toward, or end; ach other so the look in the spring namer vertes. Lever slaces \$9a. from moving dama by larger shoulder 35 someouted to the short 18. on the sade is much as to limit the longitudinal travel of the bearing plate mesters on they move together to prevent perm information of the column almost by. Warrows alternative means for preventing seeage to the column element may also be employed. For example, year or rings someted on this obest may serve as stops, or the owner 48 provided with suitable connections may be amployed for this purpose to limit longitudinal and/or lateral seflection of coinses.

The columns of the column classes 4) may be arranged around the coart 16, which as shown here theres a portion of the body of the spring derive, with made of the columns fitthed in the rease 57. The solumns may be

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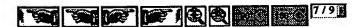


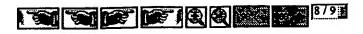


ritied closely tognitur as shows, or may be spaced around the rate, with separators used between them to meistain the desired spacing. The resolut of columns employed will depend upon column desired spacing. The resolut of construction. For excepts, the eleminators ratio of the column may be varied widnig, set the column and sey be round, flat, first or biaged. The preferred construction is a thin, eleminar column with tension ands, from to now within the recess shaped to the screening of the column case. Materials which may be astimferiority supleyed for the column are set. Materials which may be districtly supleyed for the column are set on and low alloy study, such as panesshor bronze, beryllium support, the high stokel alloys and other similar materials providing astimizationy sechanical properties. Typically, the individual columns are of long revisespalar cross-costion, with the width bring greater than the thickness, and arranged so that the wider face of the columns is somewhat to the simular of the shaft. Thus, with carficlant compression loading, the columns backle, and tend shout the said having the loast sevent of inertia, e.g., outwardly may from the shaft 15.

For example, a group of columns 0.157-inch thick by 0.575-inch wife by 10.625-inches long, with the ands rousend, were febrionized from 1.2.8.I him of the sale, quantied and draws at 775°F. But column was found to require a critical sumpression losding of 550 pounds in order to buckle the exhibit.

After buniling, the columns were frank to have a very first apring characteristic, as shown in Figure J, wherein F₀ is the critical buniting leak and point 0 represents the load and deflection at which the stress in the enterms fibers of the spring ubaracteristic curve is described by serve 04'ABO. Actually, the chape of this spring ubaracteristic curve is described by serve 04'ABO. Actually, this curve is described by care 04'ABO. Actually, this curve is described by care 04'ABO. Actually, this expresent typical vertical limits, which, of course, may be varied surprising to the application for which the spring is destined. For example, where a large master of floring spring are not moticipated, a working airnes just below the yield points may be used, while with a great number of floriness, the working stress may be held to less than the endurance limit of the anterial of construction. In the above-manifoced tests, the lateral intrinction was limited to





approximately one fuch, at which the longitudinal deflortion was approximately 0.225 inches. From more deflortion to the assume deflortion, the \$50-pound loading was found to be substantially constant.

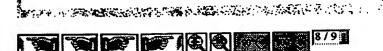
Dismother test a spring duvice was built, as down, employing 80 columns, each having a critical buckling load of 1250 possés. The internal defination was limited between 0 and about 1.00 inches by empregatately positioning the stope. Once compressional luminag, the spring element buckled at enternality 25,000 possés and from a longitudinal deficacion of 0.05 inches (buckling) to stops. 0.15 inches the lead remained substantially at 25,000 counts.

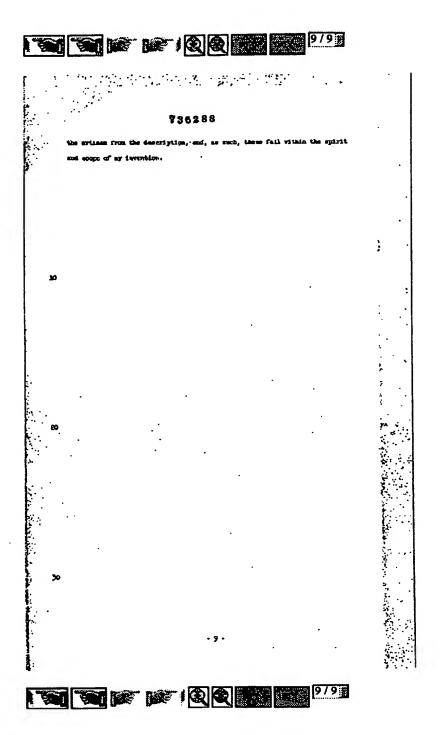
Of course, in douigning a spring elevation above it is advantageous to driven the greaters possible value of longitudinal defination for specifical values of lateral deflection and critical busiling load, while unintering the stress level to the columns at a cafe level. The preferred columns, therefore, are landarisely, as shown in Figures 13 and 2, with unitiple flat members

In the operation of the above expeding tool for setting a liner in well section, the male-up tool is lowered into the sell as mestioned above, with the area 22 is the retreated position. Then the tool is at the desired level, the well taking is retented. The friction member his capages with the wall of the means and prevents thinkle his tree revolving. With several revolutions of the taking, lower shoulder 35 is nowed measurily by differential server 9 to bushle oping almost 97 which has a predefermined critical buckling loose. This lead is transmitted wearnly against the lower cal of expender 25, and the tapered confuse is engaged with the tapered surface on the Landse of the sum 22 to ways the tapes contently with a substantially constant force proportional to the critical bushling look of the syring almost. Subsequently, the expending tool is passed through the liner to expend 10 in the caping in the secont described by each force.

The foregoing teneription of a preferred embeliance of ay investigation has been given for the purpose of examplification. It will be understood that various mathifications in the describe of association will become apparent to

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